Developments In Marine And Brackishwater Fish Culture In Southeast Asia

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ABSTRACT

Freshwater, brackishwater, and marine ecosystems are recognized as distinct from each other and aquaculture is often conventionally categorized accordingly. However, the brackishwater aquaculture category is by no means universally recognized. China, India and Japan recognize only two categories: inland and marine aquaculture. Thailand and Vietnam, on the other hand, report production from brackishwater and marine aquaculture together under one category: coastal aquaculture.

An examination of the species involved would show that there is such a wide overlap between so-called “brackishwater species” and “marine species” so that the two groups are virtually congruent with each other. Brackishwater species are euryhaline and can survive just as well in varying salinity levels and may also be raised and grown in full-strength seawater. So-called marine species, on the other hand, can tolerate slight dilutions in salinity and can be grown just as well in what are technically brackish waters. Furthermore, most, if not all, of the so-called brackishwater species invariably require marine waters for propagation. Thus, it would appear that the distinction between brackishwater and marine aquaculture is meaningless in categorizing aquaculture species.

Saltwater culture of finfish in Southeast Asia may be characterized by low species diversity; sluggish industry growth, continued use and even dependence for some species on wild-caught seedstock, and heavy dependence either on fresh fish biomass or on fish meal for formulated feeds. There are only a few of finfish species or species groups that are now commercially raised in saltwater: milkfish, tilapia, grouper, and sea bass. Mangrove snapper and rabbitfish are to a certain extent already being cultured, but have not yet reached a significant proportion. Relative to other aquaculture commodities, particularly penaeid shrimps and seaweeds, the growth of saltwater fish culture in Southeast Asia has not been particularly spectacular. This is not for lack of market since there is a good international and local market for groupers.

While milkfish and sea bass fry can now be commercially produced in hatcheries, commercial production of grouper fingerlings seedstock remains elusive, despite a long R & D history. There is an urgent need to develop cost-effective feeds with a greatly reduced requirement for fish protein for saltwater aquaculture.

A Global Retrospective

More than three thousand years ago when fish was first cultured in China during the Shang Dynasty (1401-1154 B.C.), the species known to have been cultured was the common carp (Li, 1992). All through the millennia, as dynasties came and went in China, and as civilizations rose and fell elsewhere on the globe, it appears that farmed fish was mainly produced inland, largely carps, and that China was the major producer. Today, as we enter the third millennium, the situation has not really changed all that much. Most of the world's farmed fish are still produced inland, most of it still consists of the common carp and other cyprinids, and most of it is still produced in China.

Current FAO Statistics shows that in 1997, of some 18.84 million mt of fish produced from aquaculture, 16.73 million mt or 88.8% were produced inland of which 13.27 million mt or 70.4% were cyprinids and 67% were produced in China (Figs. 1, 2 and 3). Thus, as the second millennium ends, even as man has set foot on the lunar surface and unmanned probes are being sent to explore distant planets, mankind remains largely land-bound in aquaculture as it has been more than three millennia ago.

The sea beckons. With world population having reached six billion even before the new millennium is ushered in, demand for fish will continue to grow while sea-catch dwindles and user-conflict over land and freshwater resources becomes more intense. To produce more fish in the near future, there may be no other recourse but to increasingly turn to aquaculture and increasingly turn to the sea. After all, the sea covers more than three-fourth of the planet's surface.

Towards such direction, Southeast Asia has had a long head start. Many of the Southeast Asian countries have been farming the fringes of the sea for more than just one century. The region's coastal ponds produce 54% of the world's farmed shrimps and its seafarms, more than 85% of the world's carageenophytes. However, while more than half of the world's fish from brackish and marine aquaculture comes from Asia as a whole, neither China nor Southeast Asia has a clear lead over the other regions as shown in Fig. 4.

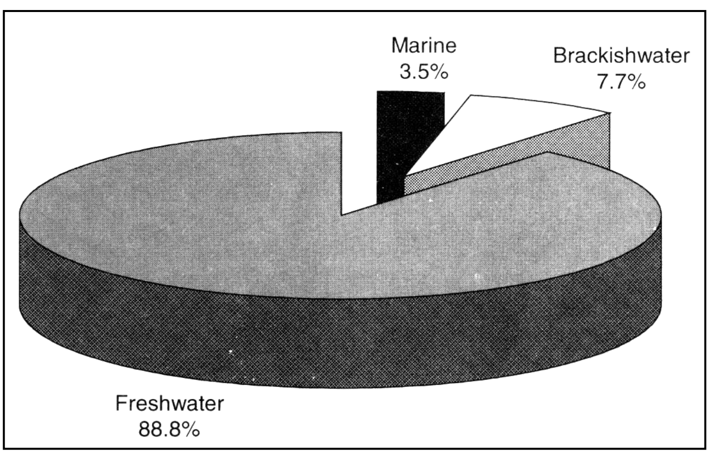

Figure 1. **Percent contribution of different aquatic ecosystems to world aquaculture fish production in 1997 (FAO, 1999)**

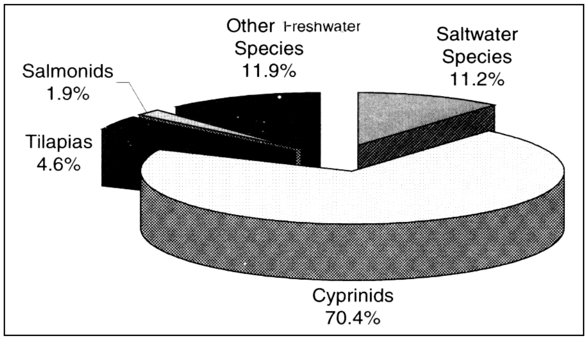

Figure 2. **Percent contribution of different species-groups to world aquaculture fish production in 1997 (FAO, 1999)**

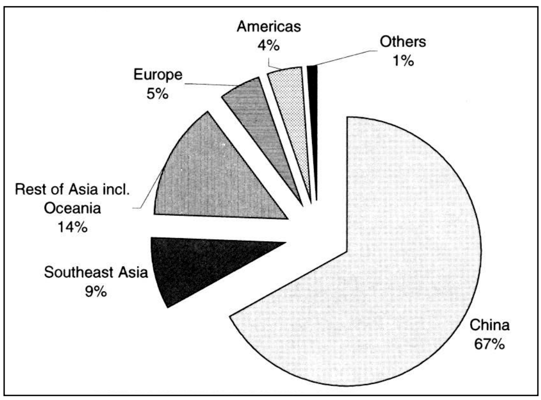

Figure 3. **Percent contribution of China and different economic regions to world aquaculture fish production in 1997 (FAO, 1999)**

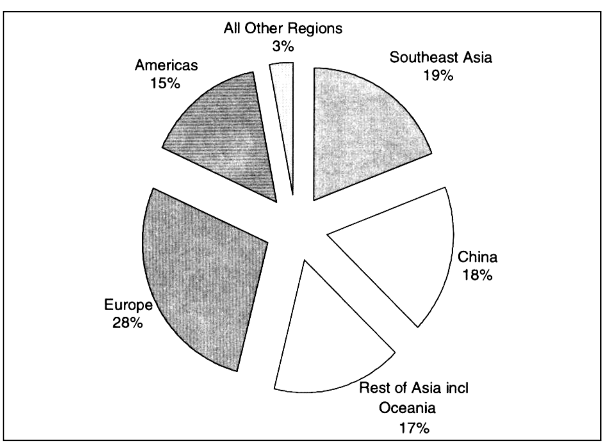

Figure 4. **Percent production of China and different economic regions to world production of fish from brackishwater and marine aquaculture in 1997 (FAO, 1999)**

A Question of Salinity

Categorization of aquaculture

When culturing fish or even when merely discussing aquaculture, one of the first parameter that comes to mind is the type of aquaculture in terms of the environment. Even before the use of the word 'aquaculture' was widely used, fish culture had always been categorized neatly into three sub-sectors based on the environment: freshwater, brackishwater, and marine. This is true in the Philippines in particular and Southeast Asia in general. This is also the system used by the Food and Agriculture Organization (FAO) in monitoring and reporting aquaculture activities and production. For a long time, this has remained unchallenged. After all it seems so logical and has a sound technical basis since it is based on the environment - or so most everybody must have thought.

Regional situation

A quick scan of the regional data reveals that the culture of a particular species is by no means uniformly categorized within the region. Singapore considers grouper culture as part of marine water culture but Malaysia, Brunei and Thailand classify it under brackishwater aquaculture. The Philippines reports the culture of grouper as part of brackishwater aquaculture if raised in ponds and as part of mariculture if raised in cages. Rabbitfish culture is similarly classified as the grouper in the Philippines but is considered part of marine water culture in Singapore. In fact, Singapore only has two categories: freshwater and marine water aquaculture.

Monitoring dilemma

The whole issue of brackishwater aquaculture as a category came up during the SEAFDEC-FAO Ad-hoc Expert Consultation on Variables and Terminology for Aquaculture Monitoring in Asia held in Bangkok, Thailand on September 13-16, 1999. Census and statistics experts anticipate difficulty in categorizing the ecosystem of a particular aquaculture activity properly due to the issue of when to consider a particular culture system as either brackishwater or marine in nature. Several "clear-cut" definitions of brackishwater were proposed for consideration by the body: 0.5 ppt to full strength seawater; less than 30 ppt but greater than 3 ppt; 0.50 to 17 ppt (Immink and Rana, 1999). These definitions clearly recognized salinity as a common factor. The census and statistics experts did not think it practical or feasible to require enumerators, who may not necessarily be aquaculturists or biologists, to bring along a salinometer just to classify an aquaculture area properly. Also as Yamamoto (1999) pointed out "salinity may differ from area to area even within the same day".

It turns out that China and Japan do not recognize brackishwater aquaculture as a category and only considers two categories: inland and marine culture (Liu and Deng, 1999; Saito and Ogawa, 1999). For the purpose of reporting to FAO, China disaggregates marine culture into marine and brackishwater culture based on the species cultured.

Thailand in their national fisheries statistics considers only two categories: freshwater and coastal aquaculture and disaggregates coastal into marine and brackishwater for FAO reporting purposes depending upon the species (Sirirattrakul, 1999). For China and Thailand, shrimps are reported to FAO under brackishwater aquaculture regardless of actual salinity. In national statistics however, Thailand which is now raising giant tiger shrimps inland, reports such production under coastal aquaculture. The Philippines on the other hand classifies fishponds as either freshwater or brackishwater while cages and pens are classified as either freshwater or marine (Recide, 1999). Thus aquaculture in coastal ponds is considered part of brackishwater aquaculture while aquaculture activities in cages or pens set in bays and coves are considered part of mariculture regardless of the actual salinity of the culture area.

India used to classify aquaculture into freshwater, brackishwater and marine but has recently changed the brackishwater aquaculture category into coastal aquaculture. This came about as a result of the Indian Supreme Court hearings on the legality of intensive shrimp farming during which the biologists and aquaculture experts failed to convince the justices that there is a clear-cut difference between brackish and marine waters. There being no legal basis to declare a water body as either brackish or marine, it was decided to classify shrimp farms as coastal rather than brackishwater ponds (Y.S. Yadava, Ministry of Agriculture, India, personal communication).

The consensus

There were strong arguments for following the Japanese model of having only two categories: inland and marine. Such a simple categorization is less subject to inconsistencies between countries and even within country from year to year. It will also make aquaculture reporting compatible with FAO capture fisheries reporting. However apprehensions were raised that the data will lose some details which may be useful for planning and management purposes.

In the end the general consensus of the countries represented in the consultation was to categorize aquaculture according to the geographic location: inland, coastal and marine. This will no longer require salinity consideration and may be more clear-cut for census taking and administrative purposes. Countries, which classify aquaculture into only two categories, may continue to do so and use the term inland and coastal or inland and marine as the case may be. Guidelines should however be made on dis-aggregating coastal or marine to coastal and marine. There is also a need to have a uniform operational definition of the coastal zone since coastal may be interpreted differently from one country to another. This classification is by no means final and may be considered only recommendatory.

Implications

One can understand the Indian Supreme Court's bewilderment over the difference between brackish and marine waters. While the brackish and marine categorization seems clear cut, it is not practical and leads to inconsistencies in reporting. It also leads to some gray areas. Some shrimp and milkfish farms for instance have been successfully operated using purely marine waters but are still considered brackishwater culture. Then there is the case of Iran. Along the Persian Gulf where the salinity normally ranges from 38 to 40 ppt, Iran is developing shrimp farms where river water is mixed with the Gulf water to bring down the salinity to 34 ppt. Does that make the water brackish?

Any reclassification of aquaculture activities is not likely to have a major impact on research and development activities since such classification is more for the purpose of planning, development and management purposes. However, it highlights the fact that while the freshwater species are distinct it is not possible to categorize the non-freshwater species as either marine or brackish in nature. Different species of fish may have their respective optimum salinity levels, but most, if not all, of the species now being farmed in coastal ponds and waters are euryhaline and as such can survive and grow almost equally well in brackish and marine waters. In fact, some ostensibly marine fish can grow as well in freshwater. The milkfish and seabass are prime examples. Regardless of their optimum salinity for growth, when it comes to propagation, all the euryhaline species cultured in Southeast Asia require full strength seawater for maturation, breeding and larval rearing. The brackish (and tidal) nature of the water supply comes into play and has to be considered in pond management but appears to have no functional value in categorizing fish species either for research or for statistical purpose.

Production Status

By country

Fish production from saline waters in Southeast Asia merely reflects world aquaculture; it takes a backseat to freshwater fish production. Of a total farmed fish production of 1.63 million mt in 1997, only 0.41 million mt comes from saline waters. Of the ten Southeast Asian countries, only one, Laos, is landlocked and is therefore limited to freshwater aquaculture. But three countries with coastlines, Cambodia, Myanmar and Vietnam do not have any report on fish production from saline waters. Myanmar and Vietnam do have coastal ponds but these are used exclusively for shrimps. Of

Table 1. **Farmed fish production by environment and by country in Southeast Asia in 1997 (FAO, 1999)**

	Production (mt)		
Country	**Freshwater**	**Saline Water**	**Total**
Brunei	30	69	99
Cambodia	11,534	-	11,534
Indonesia	356,890	237,622	594,512
Laos	14,000	-	14,000
Malaysia	26,901	6,193	33,094
Myanmar	87,306	-	87,306
Philippines	105,425	154,133	259,558
Singapore	115	818	933
Thailand	256,769	6,399	263,168
Vietnam	369,000	-	369,000

the six remaining countries, Indonesia, Malaysia and Thailand produce more fish from freshwater than from saline waters. Only Brunei Darussalam, the Philippines and Singapore produce more from saline waters. Indonesia is the region's top producer of farmed fish from saline waters with 237,622 mt followed by the Philippines with 154,133 mt as shown in Table 1. Thailand and Malaysia comes a very far third and fourth with 6,399 mt and 6,193 mt respectively.

By species

It is not possible to categorically use the term saline water species in denoting fish now raised in both brackish and marine waters. This is because some of the species now raised in such environments are clearly freshwater in origin such as for instance the Nile tilapia. In Indonesia, the Java barb (*Puntius javanicus*) is also reported as part of brackishwater aquaculture production.

Considering the diversity of marine fish, the number of species now being raised in saline waters in Southeast Asia is quite low. As many as 67 species representing some 22 families worldwide has been listed by Garibaldi (1996) as being raised in brackish and/or marine waters. This listing includes the cichlids represented by seven tilapia species. Within Southeast Asia, 17 species are listed in the statistics as being farmed in brackish and/or marine waters. However, this includes two tilapia species and one cyprinid and no production was reported for three of the species in 1997. Only eleven marine species

Table 2. **Fish production from aquaculture in saline waters in Southeast Asia in 1997. Species with no production reported for 1997 are still included to provide a complete listing of all species that have been reported farmed within the region (FAO, 1999)**

Common Name	Scientific Name	Quantity (mt)	Percent
All species		405,234	100.00
Milkfish	*Chanos chanos*	315,521	77.86
Mozambique tilapia	*Oreochromis mossambicus*	32,102	7.92
Sea bass (=Barramundi)	*Lates calcarifer*	13,419	3.31
Mullets	Family Mugilidae	11,563	2.85
Unspecified tilapia	*Oreochromis spp*	4,773	1.18
River eels	*Anguilla spp*	1,900	0.47
Groupers nei	*Epinephelus spp.*	1,492	0.37
Mangrove red snapper	*Lutjanus argentimaculatus*	1,392	0.34
Nile tilapia	*Oreochromis niloticus*	1,188	0.29
Greasy grouper	*Epinephelus tauvina*	799	0.20
Four-finger threadfin	*Eleutheronema tetradactylum*	409	0.10
Snappers nei	*Lutjanus spp*	71	0.02
Rabbitfish (=Spinefoot)	*Siganus spp*	43	0.01
Grunt	Family Theraponidae*	12	0.00
Spotted coral grouper	*Plectropomus maculatus*	-	0.00
Jacks	*Caranx spp*	<0.5	0.00
Scats	*Scatophagus spp*	-	0.00
Java barb	*Puntius javanicus*	-	0.00
Unspecified	Osteichthyes	20,550	5.07

* Percoidei in FAO Statistics since the species is reported under “Perches, breams, snappers, eels, etc.” using the ISSCAAP system of grouping species but is identified as a theraponid in Philippine fisheries statistics.

Table 3. **Aquaculture production (mt) from saline water by species groups and by country in Southeast Asia in 1997 (FAO, 1999)**

	All Countries	Brunei	Indonesia	Malaysia	Philippines	Singapore	Thailand
All species	405,234	69	235,722	6,193	154,133	818	6,399
Milkfish	315,521	-	167,900	-	147,251	370	-
Tilapias	38,063	-	31,522	-	5,939	-	602
Sea bass	13,419	69	5,400	3,487	-	243	4,220
Mullets	11,563	-	11,200	-	-	-	363
Groupers	2,291	-	-	799	605	82	805
River eels	1,900		1,900				
Snappers	1,463	-	-	1,392	34	37	-
Others	21,014	-	21,600	515	304	86	409

belonging to six families are constantly reported as being produced as shown in Table 2.

One species dominates — milkfish. A total of 315,500 mt was reported produced in 1997. All the other species combined reach only 90,000 mt. After milkfish, there are only five species groups in Southeast Asia with total aquaculture production exceeding 1,000 mt namely, tilapia, mullets, sea bass, groupers, and snappers. In Southeast Asia, milkfish is to saline water aquaculture as the carps are to freshwater. Indonesia is the highest producer of milkfish, tilapia, mullets and sea bass in saline waters.

Malaysia reports the highest snapper production and Thailand, groupers, (Table 3). Production of other species such as jacks (*Caranx sp.*) are reported from Brunei, and rabbitfish (*Siganus* spp.) and grunts (Family Theraponidae) from the Philippines, but only on an intermittent basis and at very low levels to be really significant. FAO aquaculture statistics has had an entry for threadfin shad (*Eleutheronema tetradactylum*) production from Thailand since 1992, but at a very low level of 16 mt. Since 1996, however, threadfin shad production in Thailand has jumped to 409 mt.

With the threat of disease hanging over the shrimp industry, many Philippine shrimp growers are on the look out for a viable alternative to shrimps. While many have shifted into intensive milkfish production for lack of other viable species, some have shifted to groupers. In northern Mindanao, many brackishwater fishponds are now stocking tilapia after repeated failures with shrimps. An all-male saline tilapia hybrid is now being commercially produced and promoted both as a crop in itself and as a means to reduce the risk of vibrio infection in semi-intensive shrimp culture.

Culture systems

Four different enclosure systems are employed in the farming of fish in saline waters in Southeast Asia: ponds, pens, shallow water cages, and deep-water cages. FAO statistics do not contain any information on the culture systems. However, the relative importance of each culture system in the different SEA countries may be inferred based on the general knowledge of the common practices in the culture of the different species in each country and some statistics from at least two countries, Thailand and the Philippines (Table 4).

The use of earthen ponds for raising fish is popular only in Indonesia and the Philippines with their *tambaks* and *punongs.* Vietnam and Myanmar do have coastal ponds but these are used mainly for shrimps and any fish produced are purely incidental. Malaysia has some limited production of fish in earthen ponds but high value species such as groupers, sea bass and snappers are exclusively raised in cages. Thailand and the Philippines produce sea bass and/or groupers in both earthen ponds and cages. Indonesia is known to be producing a considerable amount of groupers in cages, particularly in the Riau island group off Sumatra but somehow the production figures do not appear in both national and international statistical time series. The Riau island group is less than one hour by fast craft to Singapore. The groupers produced are apparently shipped live to Singapore without being reflected in the national fisheries statistics.

In Vietnam and Cambodia, all fish cages are considered part of freshwater culture since these are set in rivers, particularly the Mekong River. Although parts of the Mekong is also influenced by tide and are at times technically brackish, the species involved are clearly freshwater species since these are propagated in freshwater, such as for instance the Mekong catfish, *Pangasius* sp.

The Philippines has the most diverse assortment of culture systems. In addition to the tidal ponds, Filipino fish growers also use fish pens and fish cages set in shallow coves and estuaries and lately the deepwater cages that is popular in Norway and Scotland for salmon farming. Singapore

Table 4. **Relative importance of different culture systems in the culture of fish in saline waters in Southeast Asia, based on estimated production (mt) share of each culture system in each country in 1997 (FAO, 1999)**

	All Countries[a]	Brunei	Indonesia	Malaysia	Philippines	Singapore	Thailand
All systems	405,234	69	237,622	6,193	154,133	818	6,399
Fishponds	388,651		232,222	515	153,700	86	2,128
Fishpens	140				140		
Shallow-water cages	16,073	69	5,400	5,678	293	362	4,271
Sea cages	370				1800[b]	370[c]	

[a]Except for the Philippines and Thailand where data by culture systems were obtained, the data for the other countries were disaggregated by culture systems based on the species and known practices. Sea bass and groupers were inferred to have come from cages while tilapia, mullets and unspecified species normally designated "Osteichthyes nei" in FAO literature, from earthen ponds. In the case of Thailand, figures from their 1996 statistics were used as a basis to proportionally disaggregate grouper and sea bass production by culture system since the statistical frame has remained the same. A new species in Thailand's aquaculture, the four-finger threadfin, *Eleutheronema tetradactylum,* was assumed to be produced in cages.

[b]Author's own estimate based on reported number and minimum production of each cage for one growing cycle. The Norwegian-type sea cages have not yet been included in the statistical frame of the Philippine Bureau of Agricultural Statistics and therefore remains unreported. This figure is not included in the total figures, which are still based on the original figures as reported.

[c]Total milkfish reported assumed to come from cages based on reports from the industry that Singapore has started to produce milkfish using Norwegian cages since Singapore, before 1997, has no report on milkfish production and is not likely to have any area for pond development.

recently started to produce milkfish using large rectangular cages. These cages, which are set in the same areas where groupers are cultured, enabled Singapore to report milkfish production for the first time in 1997.

Industry growth

Fish culture in saline waters as an industry in Southeast Asia as of 1997 is worth US$870.6 million based on the value of the fish produced. To provide a basis for comparison, the value of shrimps produced in Southeast Asia during the same year reached US$3,479.0 million. The disparity is due not only to the fact that shrimps are more expensive than fish but also to the fact that the region now produces more shrimps than fish in saline waters. This was not always so. Indeed, up until 1991, the region was producing more fish than shrimps as shown in Fig. 5.

Somehow while shrimp culture took off, fish culture lagged behind not only shrimps but also seaweeds and even crabs and lobsters. As shown in Table 5, fish culture in saline waters grew at an average of 5.9% per year between 1984 and 1990 but only 0.9% per year between 1991 and 1997. In contrast, the shrimp industry grew at an average annual rate of 25.7% from 1984 to 1990, and 9.4% from 1991 to 1997 and seaweed 11.9% and 13%, respectively. An average growth of less than 1% means the production of farmed fish in saline waters is not even keeping up with regional population growth, which ranges from 1.06% to 2.84%. Only Singapore, Thailand and Indonesia have a population growth rate of less than 2.0% (CIA, 1999).

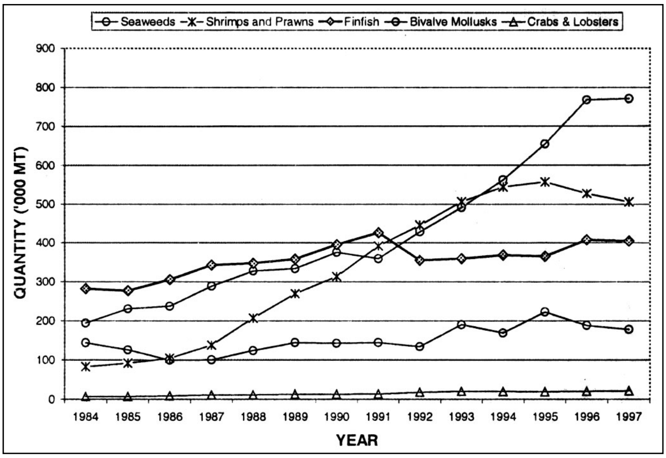

Figure 5. **World production of different commodity groups in brackishwater and marine aquaculture from 1984 to 1997 (FAO, 1999)**

Table 5. **Average annual growth (in percent) of saline water aquaculture industry by commodity group in Southeast Asia, 1984-1990 and 1991-1997**

Commodity	**1984-90**	**1991-97**
Seaweeds	11.9	13.0
Shrimps and prawns	25.7	9.4
Finfish	5.9	0.9
Bivalve molluscs	1.0	6.8
Crabs & lobsters	12.1	9.0

With the exception of Indonesia and the Philippines, saline water fish culture in all the other Southeast Asian countries is focused on the production of high value fish such as sea bass and groupers in sea cages, rather than food fish such as milkfish in earthen ponds. Earthen tidal ponds are used mainly for the culture of shrimps while food fish are produced mainly in inland freshwater areas. Most likely this situation is as much due to tradition (freshwater ponds being presumably older on the Asian continent) as it is to best economic use of tidal ponds.

Technology Status

Seed production

Aquaculture in saline waters in Southeast Asia is still heavily dependent on wild-caught fry. Of the species or species groups now being cultured in saline waters in Southeast Asia, the production of fry and fingerlings from commercial hatcheries is limited to sea bass and milkfish (Parazo *et al.,* 1990; Gapasin and Marte, 1990). The technology to propagate the striped or grey mullet, *Mugil cephalus,* in hatcheries, has been available since the mid - 1970s (Nash *et al.*, 1974; Kuo *et al.*, 1974), but there are no reports that any hatchery in Southeast Asia is producing mullet fry or fingerlings. Rabbitfish or siganids can likewise be mass-propagated (Duray, 1990) as can the mangrove snappers, *Lutjanus argentimaculatus,* but the lack of a strong demand for the fingerlings of either species appears to have hindered their full commercialization.

The mass propagation of grouper remains the equivalent of the “holy grail” to the Southeast Asian aquaculture R & D sector. The growing demand for live groupers, and the high price that affluent consumers are willing to pay for it, has driven up the prices of the dwindling supply of wild-caught fingerlings. Grouper fingerlings in the Philippines are actually priced by the “inch” and is currently at Philippine Pesos 10.00 (PhP10 or US$ 0.25) per inch. Grouper fingerlings with a total length of 15.2 cm can cost as much as PhP60 (US$ 1.50). Meanwhile, greater awareness on the dangers of cyanide fishing and more vigorous enforcement of existing laws against the practice cannot but push a shift in the production mode from fishing to aquaculture. The main constraint is a reliable supply of fingerlings.

Ever since Chen *et al.* (1977) reported on the first successful artificial spawning and larval rearing of the greasy grouper, *E. tauvina,* including the first successful hormonal induction of masculinity among mature females, most commercial grouper production are still based on the use of wild seed. Timing, size and nutritional quality of feed for early larval stages, sensitivity to disturbance and physical damage in the later larval stages and cannibalism during metamorphosis and nursing, all remain serious problems. (Datu-Cajegas *et al.,* 1998).

Commercial hatchery production of grouper fingerlings is restricted to Taiwan. It is not clear whether Taiwan has developed a better technology to enable their hatcheries to go into commercial production or that their technicians are better skilled. It is entirely possible that Taiwanese hatchery operators are just more willing and much better prepared financially, than their Filipino or Indonesian counterparts to face the risks involved in grouper fry production where survival rates may be no higher than 5% and may at times be 0%. Considering the current prices and demand for grouper fingerlings, such risks may indeed be worth taking.

There are reports that the Gondol research station for coastal fisheries in Bali, Indonesia is already extending grouper larval rearing technology to backyard hatcheries using eggs produced by the center in the same manner that milkfish hatchery technology was disseminated before. However, this is reportedly still done at a very limited scale, primarily to selected hatcheries. There has been no reported upsurge in Indonesian grouper production. In fact, Indonesian grouper production did not even appear in the FAO aquaculture statistics for 1997.

Feed technology

Feed continues to be a serious area of concern for all the species involved. Formulated diet in pellet form is now commercially produced for both milkfish and tilapia. Pelletized feed is now also available for grouper but acceptance by the fish is a problem and the fish reportedly do not grow as well as with fresh fish biomass.

The fact that feeds for some fish species are already mass-produced and marketed by no means indicate that feed technology for certain widely farmed species is already fully developed. Most if not all, of the feed now available commercially still use a considerable amount of fishmeal. Even feeds for such species as the milkfish, which can subsist and grow on a purely natural food diet consisting largely of algae, still contain some fishmeal. Carnivorous species such as sea bass, groupers and snappers on the other hand are totally dependent on fish biomass. Since it requires at least five kilograms of fish to produce one kilogram of a carnivore species, such species are in fact “protein reducers" rather than protein producers as Tacon (1994) puts it. While financially profitable due to the high market value of such carnivore species, this is hardly ecologically sustainable nor is it morally defensible in light of dwindling fish resources and still widespread problem of malnutrition. More research and development work need to be done to develop cost-effective diet, which requires little or preferably no fish protein. For intensive fish farming to be sustainable in the long term, more sustainable protein sources will need to be found and developed to replace fish meal in compounded diets. Similarly, compounded diets should be developed for carnivore species such as groupers in order to reduce if not completely eliminate the need for fish biomass.

Research need to be done not only on the diet composition but also on the form of feed most acceptable to a particular species. Groupers, for instance, do not readily take to dry pellet. Would a dough-like moist form similar to formulated eel diet (which is moistened only before feeding) be more acceptable? Feeding dynamics and optimal feeding rate, feeding time and frequency also need to be established for each species being cultured. For instance, maximum feed intake for milkfish have been observed to occur between 11 am and 3 pm and again at 5 p.m. to 6 p.m. and that actual diet intake was only 0.82 % of fish biomass (Luckstaedt et al., 1998), thus indicating a large amount of wastage using a daily feeding rate of 2 to 3% biomass as is often recommended.

Natural food optimization

There is a considerable amount of work that has been done on pond fertilization based on pond nutrient dynamics particularly under the Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP). It has been shown in experimental ponds that annual yields of as high as 11,000 kg/ha or greater can be attained for Nile tilapia using only fertilization (Knud-Hansen and Lin, 1996). This is comparable to the yields in semi-intensive milkfish ponds using pelletized feed. It has also been found that the most efficient system for Nile tilapia is to grow the fish using fertilizer alone initially, with feeding commencing only when the fish have reached 100-150 g (Diana *et al,* 1996). There is no comparable work being done in tidal ponds using saltwater fish species.

Milkfish is traditionally grown in shallow water ponds using only natural food, which could either be the filamentous green algae or the blue green algal complex known as *lablab* in the Philippines and *klekap* in Indonesia. The use of plankton as food in deep water ponds has been demonstrated to result in higher yields but has not found local acceptance in the Philippines probably due to the additional expense required to raise the dikes to the required level. The conversion of many of the milkfish ponds into shrimp culture ponds both in the Philippines and in Indonesia has resulted in the availability of deeper ponds which might be suitable for an intensified fertilizer-based culture.

The usual fertilization method that has been extended to fish farmers is based on fixed-rates without any regard to the variations among ponds or during the season. Simplified methods of determining primary and secondary limiting nutrients using algal bioassay without requiring any instrumentation or advanced training have already been developed for freshwater systems (Knudsen, 1998). Yet, these have never been verified and adapted for use in tidal ponds.

There is a clear need to encourage the use of natural food in tidal ponds by developing more effective pond fertilization techniques that is based on pond dynamics rather than on fixed rates. It should be noted that such techniques need not be limited to tilapia and milkfish since this can be applicable as well to other species with similar food habits such as mullets. Even the culture of grouper and other carnivore species may also be similarly benefited since an effective fertilization technique can also result in the higher production of prey species, the use of which is being promoted as one way of reducing feeding cost (Baliao *et al,* 1998).

Fish health management

Unlike in shrimp farming, disease thus far is not a problem of serious concern in brackishwater and marine fish culture in ponds. Milkfish, which is the dominant culture species in the region, is mostly cultured in extensive, fertilized ponds and have very low risk of infection. Even the semi-intensive and intensive milkfish farms in the Philippines are not known to have problems with infectious diseases. Although parasitic protozoa, monogenean and digenean trematodes, bacteria and viruses are known to occur in groupers (reviewed by Baliao *et al.,* 1998), no case of mass mortality that can be attributed exclusively to such causes has been reported in brackishwater ponds. This is most likely due to the relatively lower level of industry development as compared with shrimps.

In contrast, reports of mass mortality are common for fish cage and fish pens set in shallow bays and estuaries regardless of species cultured. Subasinghe and Sharif (1996) have noted that environmental pollution-related problems are becoming increasingly important in marine cage culture. The pollution may come from external sources such as sewage discharge, industrial and agricultural effluents. Often times however, this may be self-induced being the result of over-stocking and satiation feeding with high protein diets - typically fish biomass. Such practices increase the organic loading and nutrient content in culture waters resulting in high bacterial loads. With the deterioration of water quality, dissolved oxygen and pH may become critical and result in mass mortalities.

In the Philippines, health problems are recognized by fish farmers as a constraint to grouper culture in cages. Clinical signs such as ulceration, exopthalmia, fin rot, tail rot, scale loss and white spots due to unknown causes have been observed to result in high mortality especially during the fry stage. This has been attributed to the proliferation of pens and cages, unstable climatic conditions and run-offs following heavy rains, leading to the deterioration of water quality (Somga *et al.,* 1999).

Since environmental deterioration appears to be the major problem confronting the cage and pen culture industry, the obvious solution is to have measures instituted to regulate spacing of cages and loading rate. While regulation is the domain of government agencies, research is needed to come up with the necessary data to formulate workable and effective regulations.

Various control and preventive measures for fish diseases are already practiced widely in Asia. Several common chemicals, drugs and antibiotics are already used in controlling fish diseases. However, immunization or vaccinations as a preventive measure is not used in Asian aquaculture. Instead, the use of natural products such as herbal medicines are often used in China and India (Subasinghe and Sharif, 1996). In the Philippines small-scale fish cage farmers reportedly use guava leaves and jackfruit peelings to treat white spots and tail and fin rots in groupers (J.R. Somga, personal communication). The use of such indigenous materials has not yet been scientifically validated. Furthermore, there is no report of any present or future research to screen indigenous plants for their potentials as disinfectant or therapeutant for fish.

Enhancing or manipulating growth and sexuality

Marine fish aquaculture in Southeast Asia is still at the stage of improving larval survival in the hatchery. Therefore, any talk of improving the stock either through selective breeding or development of transgenic strains as is now being done with salmonids can be considered premature. Meanwhile, all of the species now being cultured in saline waters are harvested long before they reach sexual maturity, so the question of manipulating sexuality at the fry stage to achieve a more uniform growth rate as is done with tilapia may be considered moot and academic.

Mention however has to be made on the success in inducing early masculinity of the orange-spotted grouper, *Epinephelus coiodes,* using male hormones instead of having to wait for 5 to 6 years (Tan-Fermin, 1992; Tan-Fermin *et al.,* 1994). This technique, which was developed more than 20 years ago (Chen *et al.,* 1977), has been recently refined by using silastic implants. Thyroid hormones have also been successfully used to improve survival of pre-metamorphic grouper larvae (De Jesus *et al.,* 1998).

One of the most exciting developments in marine fish culture is the molecular cloning of the growth hormone (GH) complementary DNA (cDNA) in the rabbitfish (*Siganus guttatus*) using *Eschirichia coli* as biological amplifiers (Ayson *et al.,* 1998). Similar work on milkfish (*Chanos chanos*) is reportedly also in progress. This development, it is hoped, will lead to the mass production of species-specific growth hormones, which might be used to accelerate fish growth once a suitable delivery or application method can be developed.

Engineering

Pond engineering in terms of dike design in relation to the soil characteristics of an area and size of supply and drainage canals and gates in relation to the culture system is already a mature technology since it is merely the application of civil engineering principles to aquaculture. However, the new concern over the effects of aquaculture, more specifically intensive aquaculture, on the coastal environment has meant putting pond-engineering back to the drawing board in a figurative and literal way of speaking.

In terms of degradation of the coastal environment, the focus now is on shrimp farming rather than fish farming. This is mainly because most of the intensive coastal aquaculture operations in the region are engaged in the production of shrimps rather than fish. It is probably only in the Philippines that intensive fish farming in coastal ponds is being pursued using erstwhile shrimp farms. But, whether raising shrimp or fish, once intensification is practiced, a much higher organic load in the wastewater can be expected. Thus, the problem can be considered common to both aquatic commodities.

One possible approach to greatly minimize if not completely eliminate the polluting effect of intensive aquaculture is to employ low or even zero water discharge systems. Such a system requires the treatment of wastewater using mechanical and biological means and re-using the treated water instead of drawing in new water. This clearly is a problem in aquaculture engineering. Since it can be assumed that very few new areas, if any remains for new aquaculture development, the focus shall be on retrofitting existing pond systems. While actual designs will be farm-specific, it is necessary to establish basic parameters such as the optimum ratio of treatment ponds to culture ponds, residence time of water in the treatment ponds relative to species, stocking density, feed type and feeding rates.

Beyond the coastal ponds, engineering is also required in designing affordable sea cages and mooring systems durable enough to be set in relatively open and deep waters. Most of the present fish cages are set in shallow waters using light materials such as bamboo. Such location is not ideal for two reasons. One is that such structures occupy near-shore communal fishing grounds which often are the only fishing grounds accessible to small fishers whose only means of propulsion may be a wooden oar. The second is that shallow waters are easily silted and degraded since circulation is more limited and is further reduced by the fish cages or pen structures. Available deep-water cages are priced far beyond the means of most fishers.

Issues and Constraints

Species diversification

As discussed earlier, the number of fish species cultured in brackish and marine waters in Southeast Asia is very limited. There is a need to screen fish species for their aquaculture potential or to at least develop the propagation protocols for more species. Of particular interest are species, which already have a good market, such as the jacks or carangids and those, which may be low in the food chain, spadefish or scats. Some of the species found to be fast growing may not be immediately marketable, but this is another matter and will be discussed in a subsequent section.

There are at least three good reasons for increasing the number of fish species in aquaculture. One, it will give both growers and consumers more choices. Two, it may improve market prospects since fish farmers need not flood the market with the same product and some may even have the option to cater to niche markets. Three, stock enhancement using hatchery-reared fry may be the only way to re-populate depleted fishing grounds.

Food versus cash

There is one of school of thought espousing that aquaculture development should be guided towards the production of food fish, i.e., low trophic level species which can be produced at a low cost and can be mass marketed as a cheap source of animal protein. Some research institutions and international donor agencies as well as individuals have this kind of orientation. While such view is valid, it is not flawless. To produce fish at a low cost, the only alternative is to use fertilizers rather than feeds. This means the use of ponds rather than cages. Pond-based aquaculture requires access to land and considerable capital to construct the ponds. This puts fish culture in coastal waters out of reach to the poor.

The only way for the poor to engage in fish culture is to use cages. And the only option to earn enough to support one's family using a few square meters of net cages is to culture high-value species. Cages do not require land. The coastal waters, at least, is still common property and cages do not require large capitalization. With the sale of a few kilograms of groupers, one can already buy rice and other basic staples including not only lower value food fish but also meat. One can find such operations throughout the region.

Environmental considerations

Whether ponds or cages are used, the impact of fish culture or other aquaculture activities, on the environment is already well known. To construct tidal ponds, mangrove forests were traditionally clear-cut. With so little original mangrove left and with greater environmental awareness on the part of most countries and governments, such practice is already discouraged if not completely halted in most of Southeast Asia. At any rate when intensification became practiced, and mere tidal exchange became insufficient, it became clear that the mangrove was not the best area after all and there was a shift to the use of low-lying coastal agricultural lands with its attendant conflict with agriculture.

The impact does not end with the clearing of mangroves and the possible salinization of agricultural lands. Aquaculture, it turns out, also pollutes especially if conducted on an intensive basis. In present-day Southeast Asia, this is of course happening only in shrimp culture. This is so because, as was explained earlier, with the exception of Indonesia and the Philippines, most of the coastal ponds in the region are used primarily for shrimps and most of the brackishwater fish culture in the two countries is done extensively or at most semi-intensively.

This situation may not be for long, however. Depending on the bio-technical as well as the demand and supply situation, it will be quite easy for the present day extensive fishponds to intensify or for intensive shrimp farms to shift to intensive fish culture. This is already happening to a certain extent in the Philippines where because of the recurring disease problem affecting shrimps and the high local demand for milkfish, pond operators shifted back to milkfish but this time on an intensive level. Thus far, pollution from such practice is not evident yet. Perhaps because as practiced now, intensive milkfish farming is not as widespread as shrimp farming was in its heyday. If intensive fish culture becomes the norm, auto-pollution could very well also happen in fish culture as it did in shrimp culture.

The potential of intensive milkfish farming in polluting the environment has been amply demonstrated in fish pens and fish cages set in shallow waters in the province of Pangasinan, Philippines. With the fish cages and pens set so close to each other, circulation of water was hampered and the normal tidal exchange apparently was not able to adequately freshen the coastal waters. Fish kills became a recurring problem. Set close to the shores, the pens and cages not only hamper the access of small fishers to their traditional fishing grounds but also reduce the available fishing ground.

Sea cages which are designed for installation in deeper waters (30 to 50 m) have not yet been in use for long within Southeast Asia. So far, the 60 units or so that have been installed within Sual Bay, Pangasinan, Philippines do not appear to have the same problems as the shallow water pens and cages have. For one, the units are positioned farther from each other while the deeper water allows better circulation. This does not mean they are completely without any negative impact to the environment.

The effect of salmon cages in northern Europe particularly Norway and Scotland is well documented. Gowen and Bradbury (1987) as cited by Barg (1992) estimated that a salmonid farm producing 50 mt of fish requires 100 mt of food of which only 80% is consumed. Of the portion consumed, 10,560 kg carbon and 616 kg nitrogen are released to the marine environment as fecal waste while 3,203 kg ammonium-nitrogen and 801 kg of urea-nitrogen are released as excretory waste. The 20% that are uneaten contain 8,800 kg carbon and 1,540 kg of nitrogen. There is still no similar study made on milkfish cages in the Philippines but it is well to note that each 19-m diameter cage has been found to be capable of producing at least 30 mt of milkfish in 4 to 5 months.

Marketing and economics

Aquaculture operation does not end with successfully breeding and growing a particular species. Unless the product is marketable at a price that will allow the producer to recover capital cost, production costs plus a profit margin that is significantly higher than bank placement rates, then the operation cannot be considered successful. High survival rates and fast growth rates are meaningless if these can be achieved only at a cost that far exceeds the prevailing market value of the fish produced. The converse is also true. Lower survival rates and lower growth rates do not matter if it is the only way to make the operations profitable.

Fish price like that of most other commodities is governed by the supply and demand situation. Due to such characteristic, the production of milkfish in the Philippines typically goes through a boom and bust cycle. When milkfish supply is low, prices go up thus encouraging growers to intensify and produce more. When the growers start unloading their produce in the market, prices go down thus discouraging many from stocking too much the next time. Once supply is low, prices go up and growers are encouraged to stock intensively again. This is exacerbated by the fact that the market for fish is not rigidly species-specific. Thus an abundant sea-catch can pull down the prices of milkfish as occurred in the Philippines in 1997-98 during the height of the El Niño phenomenon.

On the other hand, while consumers may exercise some flexibility as to species depending upon the price, there is also strong regional preference for or against certain species. This issue has to be considered if brackish and marine water aquaculture is to have a broader species based. Within Southeast Asia, milkfish is eaten only in the Philippines and Indonesia and, even within these two countries, there are localities where the species is more highly desired than in others. Sea bass meanwhile is highly sought in Thailand, Malaysia and Indonesia but has a highly localized market in the Philippines where it is popular only in the Western Visayas area.

Due to consumer biases and preferences, the aquaculture industry typically falls into a rut wherein all growers are producing the same fish species year after year thus further bringing down prices due to over supply. Yet, it need not remain so. Fish can also be marketed and promoted just like the proverbial soap or toothpaste. The experience of the channel catfish in southern United States is a classic example. Catfish used to have a highly regional market limited to the American south. Elsewhere in the US, consumer acceptance used to be a big problem. Even its very name "catfish" does not sound too appetizing. In 1986 in an effort to expand the market and save the industry, catfish producers in the state of Mississippi agreed to a voluntary $6 per ton assessment on feed to fund market development. The effort paid off. A net producer return of $0.48 to $7.46 per media dollar expended suggest that the industry's advertising effort was a profitable activity for the catfish producers. Despite its small budget the catfish advertising program has been successful both in terms of increasing consumer demand for catfish and improving the net returns of catfish producers (Kinnucan and Venkateswaran, 1991).

Social equity

The common perception is that coastal aquaculture is always a big-time operation and is exclusive to rich individuals or large corporations. This may be partly true in the Philippines but is by no means universally true throughout Southeast Asia. In the Philippines, a 1977 survey of brackishwater ponds, whether privately owned or public land under a fishpond lease agreement (FLA) showed that 79.3% by area but only 35.1% by number are more than 10 ha (Table 6; Librero *et al.,* 1977).

The picture has not changed much more than 20 years later. As shown in Table 7, based on a total count using actual licensing records, 77.8% by area but only 34.7% by number of the fishponds under FLA in 1998 are more than 10 ha in size. In contrast, the backbone of Thailand's immensely

Table 6. **Size-frequency distribution of a random sample (n=l,175) of brackishwater fishponds in the Philippines, whether under Fishpond Lease Agreement (FLA) or privately-owned, by number and by area (Librero *et al.,* 1977)**

Size-class	Number	Percent number	Area (ha)	Average area (ha)	Percent area
1 ha and below	178	15.2	110.01	0.62	0.9
1.01 to 5.00 ha	392	33.4	1,109.39	2.83	8.6
5.01 to 10.00 ha	192	16.3	1,457.85	7.59	11.2
10.01 to 20.00 ha	201	17.1	2,926.86	14.56	22.6
20.01 to 50.00 ha	153	13.0	4,768.12	31.16	15.3
More than 50 ha	59	5.0	5,367.07	90.97	41.4
All sizes	1,175	100.0	15,739.30	13.40	100.0

successful shrimp culture industry are the small farmers who make up 80% of the 12,500 intensive shrimp farms, each consisting of 1 to 2 ponds, ranging in size from 0.16 to 1.6 ha (Kongkeo, 1995).

With all the coastal tidal lands already occupied, there's little hope for the smallholders to acquire coastal fishponds in the Philippines unless fishponds once again is subject to agrarian reform as they were briefly in 1987 under the Comprehensive Agrarian Reform Law. This is not likely to happen in the near foreseeable future. Thus it appears that for the coastal poor in the Philippines the only avenue for them to engage in aquaculture as a livelihood is to use cages instead of ponds. As shown in Table 8, fish cages do not require large investments and give adequate financial returns.

Table 7. **Size-frequency distribution of brackishwater fishponds in the Philippine under Fishpond Lease Agreement (FLA) by number and by area (based on BFAR FLA Records as of November 1998)**

Size-class	Number	Per cent Number	Area (ha)	Average area (ha)	Percent area
1 ha and below	111	2.4	72.041	0.649	0.1
1.01 to 5.00 ha	2,418	51.5	9,458.368	3.912	15.1
5.01 to 10.00 ha	537	11.4	3,925.285	7.310	6.3
10.01 to 20.00 ha	678	14.4	9,742.785	14.370	15.5
20.01 to 50.00 ha	852	18.2	26,471.038	31.069	42.3
More than 50 ha	98	2.1	12,956.310	132.207	20.7
All sizes	4,694	100.0	62,625.827	13.34168	100.0

Table 8. **Comparative economics of pen/cage farming by species (in Philippine Pesos), Lingayen Gulf, Philippines, 1997. Figures are average values (adapted from various tables in Morales and Padilla, 1998)**

	Milkfish	Grouper	Siganid	Polyculture
Number of farms in sample	80	6	5	4
Farm size (m^2)	1,385	170	160	207
Investment cost	66,962	13,517	10,768	12,350
Fixed cost per cropping	7,629	1,424	1,473	1,944
Variable cost per cropping	88,415	36,112	31,285	15,317
Production per cropping (kg)	8,875	169	355	Milkfish 148 Siganid 176
Farm-gate price	61	332	118	
Gross revenue	195,339	55,886	41,914	24,364
Net profit	99,037	18,013	8,567	6,514
Culture period (mo)	4.0	6.7	3.9	3.75
Margin for profit and risk	4,815	2,841	1,667	694
Imputed family labor	590		2,839	2,839

Gross profit = Revenues - Variable costs
Net profit = Gross profit - Fixed costs

Prospects for the New Millenium

Southeast Asia has considerable potentials for the farming of saline water fish in coastal ponds and waters. It has the resources for saline water fish culture in the form of coastal ponds, it has a strong tradition for aquaculture, and it has the technical manpower. The region's ponds are now mostly being used for raising shrimps primarily because of the continued strength of the global shrimp market. But these can always be shifted to fish production if and when the market for a particular fish species gains strength and its production prove to be equally or more profitable than shrimp farming.

Such shift is already happening in a limited scale in the Philippines where at least one farm has shifted totally from growing black tiger shrimps to groupers without requiring any physical modification. While many other erstwhile shrimp growers are looking on with interest in view of the continued onslaught of luminescent vibriosis in shrimps, two factors are proving to be major deterrents: the lack of a reliable supply of grouper fingerlings and the need to use fish biomass as feed. What is true for grouper is applicable as well to other high-value marine species. These two constraints, it is hoped, can be addressed during the early part of the new millenium as hatchery technologies for grouper and other fish species become commercially viable and acceptable feeds are formulated.

The successful use of marine cages set in relatively deep waters for milkfish in the Philippines points out to their potential in helping address the issue of food fish security as the catch from capture fisheries continues to dwindle. One 19 m diameter cage can produce a minimum of 30 mt milkfish in 4 to 5 months. Taking the Philippines as an example, the country's projected shortfall of some 300,000 mt by year 2005 can be filled by using only 5,000 units of such cages. All in all the 5,000 units will occupy no more than 180.5 ha. In fact, the entire Philippine milkfish production from brackishwater ponds which in 1998 reached only 141,073 mt could have been produced only in 2,351 such cages. This means all these erstwhile mangrove forests could be replanted without jeopardizing the supply of milkfish in the Philippines by the simple act of shifting to cage culture.

But there's a catch. Although mangrove-friendly fish cages may not be coral reef friendly. As discussed earlier, a fish cage also produces a large amount of organic waste, which invariably settles on the seabed. If installed over or close to a reef area, the waste can smother a coral reef. And here's another catch. These cages as presently designed and installed are terribly expensive. As currently installed, these cages can not possibly be promoted as an alternative livelihood to fishing for the small fishers. Thus, two things should be addressed at the start of the new millenium. Areas where such cages can do the least harm should be identified and smaller and more affordable cages should be designed for individual ownership by small fishers. Towards both ends, the concept of designating a mariculture park should be seriously studied. Such a mariculture park will not merely designate an area for cage installation but will actually provide mooring facilities just like a marina. And like in a marina, fish cage operators can pay a mooring fee. Mooring in deep waters can easily cost as much or even more than the cage itself. With such infrastructure provided and with smaller cage units, marine cage culture technology can be made affordable to the coastal poor.

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